**Conference Call**
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Ray,

Attached is a copy of Dr. William Galloway's Direct Testimony in UEC's contested case hearing. Because we will be sending you pertinent excerpts from his testimony in a follow up email, I thought I would provide you with a full copy. It is my understanding that Region 6 has already been given a full copy of the contested case hearing record but to save time and stay focused on the very few issues outstanding, I am sending you a copy. I hope to have our brief write-up for tomorrow's call out to you shortly. Have a good evening.

craig w. holmes Galloway Direct.pdf

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SOAH DOCKET NO. 582-09-3064 and TCEQ DOCKET NO. 2008-1888-UIC
consolidated with
SOAH DOCKET NO. 582-09-6184 and TCEQ DOCKET NO. 2009-1319-UIC

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| APPLICATION OF | § | BEFORE THE |
| URANIUM ENERGY CORP | § | STATE OFFICE |
| FOR PERMIT NO. UR03075 AND FOR AQUIFER EXEMPTION | § | OF ADMINISTRATIVE |
| AND FOR PRODUCTION AREA AUTHORIZATION UR03075PAA1 | § | HEARINGS |
| IN GOLIAD COUNTY, TEXAS | § | |

# DIRECT TESTIMONY AND EXHIBITS

OF

DR. WILLIAM GALLOWAY

ON BEHALF OF

URANIUM ENERGY CORP

January 15, 2010

**DIRECT TESTIMONY AND EXHIBITS OF**
**DR. WILLIAM GALLOWAY**

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## DIRECT TESTIMONY OF WILLIAM GALLOWAY

### I.

### QUALIFICATIONS AND AREAS OF EXPERTISE

**Q: Please state your name, place of employment, and business address for the record.**

**A:** My name is William Galloway. I am the Morgan Davis Professor Emeritus of Geological Sciences in the Department of Geological Sciences at the University of Texas at Austin. I am also a Research Professor at the Institute for Geophysics at the University of Texas at Austin. My business address is 10100 Burnet Road, Austin, Texas 78758.

**Q: What is your role in this proceeding?**

**A:** I am providing expert testimony on behalf of Uranium Energy Corp ("UEC") regarding the geology of the area within the proposed permit boundary (the "Mine Permit Area"), which is identified on **Exhibit UEC-Holmes 3**.

**Q: What is the scope of your expert testimony?**

**A:** I will be testifying primarily regarding the geological characteristics of the Mine Permit Area and the uranium deposits located there. To understand the geological characteristics of a particular area, it is generally helpful to examine it in the context of the broader geologic system of which it is a part. And to understand the present day geological characteristics of an area, it is generally helpful to have an understanding of geological history of that area, such as how and when the various structures were formed. So my testimony will include a description of the broader geologic structures of which the Mine Permit Area is a part and will also include some discussion about the geologic history of the area. In my testimony, I will address matters relevant to the following issues: 1) Issue G (Does the application adequately characterize and describe the geology and hydrology in the proposed permit area, including fault lines, under the applicable rules?); 2) Issue Q (Whether the Gulf Coast Aquifer is a confined aquifer in the areas of Goliad County where UEC will conduct UIC activities); 3) Issue R (Whether mining fluids will migrate vertically or horizontally and contaminate an USDW (underground source of drinking water)); and 4) Issue T (Whether any USDWs within Goliad County will be adversely impacted by UEC's proposed in situ uranium operations).

**Q: What is your educational background and work experience?**

**A:** My educational background and work experience is set forth in detail in the *Curriculum Vitae,* which I prepared and have attached to this prefiled testimony as **Exhibit UEC-Galloway 1.**

**Q: Please summarize your educational background in broad terms.**

**A:** I received a B.S. degree in geology from Texas A&M University in 1966, an M.A. degree in geology from the Department of Geological Sciences at the University of Texas in 1968, and a Ph.D. in geology from that same department in 1971.

**Q: You testified that you are currently an Emeritus Professor in the Department of Geological Sciences at the University of Texas and a Research Professor at the Institute for Geophysics at the University of Texas. How long have you held those positions?**

A: I was a teaching professor in the Department of Geological Sciences from 1986 until 2003. In 2003, I became an Emeritus Professor in the Department of Geological Sciences and a Research Professor at the Institute for Geophysics.

**Q: What did you generally do as a teaching professor in the Department of Geological Sciences?**

**A:** Broadly speaking, I conducted research, wrote papers for scientific journals, served on committees and professional organizations that are related in various ways to research and writing in the field of geology, taught various courses in geology at both the undergraduate and graduate levels, and supervised graduate students who were conducting research and writing.

**Q: What do you generally do as a Research Professor at the Institute for Geophysics in those capacities?**

**A:** Again, broadly speaking, I conduct research and write papers for scientific journals. I also continue to be active in various professional organizations that are related in various ways to research and writing in the field of geology.

**Q: Please briefly summarize your work experience prior to your becoming a professor in 1986.**

A: I spent ten years working as a Research Scientist and then a Senior Research Scientist for the Texas Bureau of Economic Geology. Prior to that, I was employed by Continental Oil Company Exploration Research Division ("CONOCO") for several years. I began as a Research Scientist and ended up as the Director of the Geologic Section of CONOCO's Exploration Research Division.

**Q: Do you specialize or focus on any specific topics or subject areas in geology?**

**A:** Yes, my overall area of specialty is sedimentary rocks. More specifically, my work has been and continues to be focused in the areas of stratigraphy, terrigeneous clastic depositional systems, and sedimentary uranium deposits.

**Q: What are sedimentary rocks?**

**A:** Sedimentary rocks are formed through the accumulation and subsequent consolidation of sediments (*i.e.*, unconsolidated materials) deposited by rivers, oceans, wind, or ice. While there are different types of sedimentary rocks, my work has focused on what are known as clastic sedimentary rocks. Such rocks are formed from sediment that consists of particles or fragments of rocks that have eroded from the earth's surface. This sediment is transported along the earth's surface by wind, water, or glaciers and then deposited into basins. A basin is any area on the earth's surface that is subsiding and thus permits the net accumulation of sediment. The processes by which sediment is transported and deposited into a basin by flowing rivers are known as fluvial processes. Thus, river channel deposits – *i.e.*, layers of accumulated sediment transported and deposited by the flow and action of rivers – are fluvial deposits. Over time, sediment accumulates on the basin floor and forms into various layers. As layer upon layer of sediment is deposited on top of each other, each layer becomes more and more compressed under the weight of the younger layers. Eventually, the layers of sediment turn into layers of rock, which is known as sedimentary rock (or, more specifically, clastic sedimentary rock). Geologists group these layers into various formations.

**Q: What is a formation?**

**A:** A formation, which is also called a geologic unit, is simply a volume or group of sedimentary rock layers of a given age range and composition (*e.g.*, sandstone, shale, limestone). In any given basin, the subsurface is comprised of many such layers that geologists have grouped into various formations. The youngest units are generally nearest the surface and the oldest units are generally deepest in the subsurface. A given formation is typically comprised of many horizontal sedimentary rock layers.

**Q: Can you explain your specific areas of specialty in lay person's terms? First, what is stratigraphy?**

**A:** Stratigraphy is the branch of geology that involves the study and classification of sedimentary rock layers on and under the earth's surface and on their chronological framework.

**Q: In lay person's terms, what are terrigeneous clastic depositional systems?**

A: Depositional systems are geographically associated environments and processes that result in the transport and accumulation of sediment in basins. Terrigeneous clastic depositional systems are those depositional systems that result in the accumulation of sediment particles eroded from pre-existing rocks (*i.e.*, sand, gravel, and mud) and transported to basins. In other words, they are the environmental systems by which clastic sedimentary rocks are formed.

**Q: What do you mean when you say that you specialize in sedimentary uranium deposits?**

A: One of the primary focuses of my work has been the study of uranium deposits, particularly those found in sedimentary rock layers comprised of sand or sandstone. I have conducted extensive research and authored numerous scholarly papers on the geology of uranium deposits. I have organized and taught multiple short courses and continuing education programs on the subject of uranium deposit geology and geohydrology for industry, for other universities, and for professional societies. I organized and was principal lecturer for the Texas Bureau of Economic Geology research colloquium entitled "Depositional and Groundwater Flow Systems in the Exploration for Uranium."

**Q: How do your other specialty areas relate to the study of sedimentary uranium deposits?**

A: By studying terrigeneous clastic depositional systems and applying the methods of stratigraphy, a geologist is able to better understand the nature of sedimentary uranium deposits. For example, stratigraphy has long played an important role in the oil and gas industry and the uranium industry in terms of predicting identifying regions or formations that are likely to be mineral-bearing. Application of the principles and methods of depositional systems analysis tells us that cyclical changes in depositional environments cause large lateral shifts in the depositional patterns of river or ocean sediments. These lateral shifts create alternating layers of sands (which is porous and permeable and thus capable of acting as a water reservoir) and mud (which is impermeable and thus capable of providing a reservoir "seal" between the layers of sands). Understanding the depositional systems that formed deposits not only greatly reduces the time and cost of exploration by focusing only on the areas most likely to be mineral-bearing, but also provides information that is useful in developing successful mining and restoration strategies.

**Q: During your forty year career, have you focused on any particular geographic region?**

**A:** My work has concentrated on the Gulf Coast region in general. My work on uranium deposits has focused on the South Texas inner coastal plain, in an area known as the South Texas Uranium Province. The South Texas Uranium Province extends along a 300-mile belt from Starr County at the international border with Mexico northeastward through Zapata, Jim Hogg, Brooks, Webb, Duval, Kleberg, McMullen, Live Oak, Bee, Atascosa, Karnes, Wilson, Goliad, and Gonzales counties. The South Texas Uranium Province is a part of the larger Gulf Coast Uranium Province, which lies along the northwestern Gulf of Mexico in South Texas and adjacent Mexico.

**Q: When did you begin to focus on these regions?**

**A:** My focus on these regions began at the start of my career, when I was employed at CONOCO as a Research Scientist and later as the Director of the Geologic Section of the Exploration Research Division. My work at CONOCO focused on uranium and copper deposits. I studied the geologic framework in which the uranium deposits exist and the geological and geochemical processes by which the uranium became mineralized. My work also focused on developing and evaluating technology for use in exploring for uranium deposits. Projects on which I worked ranged from the South Texas Uranium Province to New Mexico and Wyoming.

**Q: Did your focus on these regions continue during your employment as a research scientist with the Texas Bureau of Economic Geology from 1975-1983?**

**A:** Yes, in fact, my focus on these regions greatly intensified during my employment with the Texas Bureau of Economic Geology. Much of my work there consisted of the study of uranium deposits found in the South Texas Uranium Province. As part of that work, I further examined the origin of the uranium deposits, the geologic framework in which the uranium deposits exist and the geological and geochemical processes by which the uranium became mineralized. In addition, I studied the geohydrology of the areas containing the uranium deposits. I also evaluated the resource potential of these uranium deposits by, for example, studying the geological attributes and depositional systems of metalliferous aquifers in which the deposits are found and assessing the potential impacts of in situ uranium mining on those aquifers.

**Q: Did your work at the Texas Bureau of Economic Geology result in any significant publications?**

**A:** Yes, I am senior author or co-author of a dozen Reports of Investigations concerning the geology of the Texas coastal plain published by the Texas Bureau of Economic Geology. Seven of those Reports of Investigations specifically concern uranium deposits and mining. For example, during my employment with the Texas Bureau of Economic Geology, I conducted detailed studies of, and authored or co-authored several Reports of Investigations regarding, the sedimentary depositional systems of two major formations located in the South Texas Uranium Province: the Catahoula and Oakville formations. Both of these formations consist of layers of uranium-bearing sand or sandstone separated by layers of clay or silt. The studies that I conducted and the Reports of Investigations that I authored addressed every significant geological approach to the characterization of these formations as related to the uranium resources located there.

**Q: Since leaving the Texas Bureau of Economic Geology and becoming a professor in the Department of Geological Sciences at the University of Texas and a research professor at the Institute for Geophysics at the University of Texas, has your work continued to focus on the Gulf Coast region in general, and on the South Texas Gulf Coast region in particular?**

**A:** Yes. I am author or co-author of numerous articles on geology and geohydrology of uranium deposits in professional journals, the majority of which are focused on the Gulf Coast Uranium Province, including a summary report on South Texas for the International Atomic Energy Agency. Also, I continue to consult with Texas Bureau of Economic Geology staff on projects regarding current groundwater quality issues arising from the presence of arsenic in the aquifer systems located in the South Texas Uranium Province. My research of the past fifteen years has focused primarily on the regional geologic framework of the northern Gulf of Mexico basin. In addition, I am the principal scientist for an industry consortium housed in the Institute for Geophysics at the University of Texas that has developed and continues to update a regional database for prediction of sandstone reservoirs suitable for hydrocarbon exploration within the basin.

**Q: Based on your education and work experience, do you consider yourself to be an expert on issues associate with the geology of the South Texas Uranium Province, including the uranium deposits located there?**

A: Yes, I do.

**Q: Do you adopt Exhibit UEC-Galloway 1 (*Curriculum Vitae* of William E. Galloway, PhD) as your testimony regarding your qualifications as an expert in the areas identified in the previous questions?**

A: Yes.

**Q: Do you have specific familiarity and expertise with respect to UEC's proposed in situ uranium mining project in Goliad County involved in the present docket?**

A: Yes.

**Q: Have you visited the Mine Permit Area?**

A: Yes.

**Q: Have you reviewed UEC's Mine Application?**

A: Yes.

**Q: Have you also reviewed UEC's PAA-1 Application?**

A: Yes.

## II.

## GENERAL HYDROGEOLOGY DEFINITIONS AND CONCEPTS

**Q: I'd like to ask you to explain some hydrogeology terms and concepts. First, what is the scientific definition of an "aquifer"?**

A: In the most general geological use of the term, an aquifer is any geologic unit or units, or portions of units, that are water bearing. More commonly, though, the term "aquifer" is used to mean one or more geologic units, or portions of units, that contain, and are capable of yielding, a useful or significant amount of water for domestic, agricultural, or commercial purposes.

**Q: What kinds of materials are aquifers comprised of?**

**A:** Most aquifers are comprised of either: 1) permeable rock, such as sandstone or limestone; or 2) unconsolidated sediment (that is, sediment that has not yet fully consolidated into rock), such as sand or gravel. Some aquifers are comprised of fractured rock (such as granite).

**Q: What is the difference between groundwater and surface water?**

**A:** Surface water is water that is found on the surface of the earth, such as water in a river or lake. Groundwater is water that is contained in the subsurface (that is, beneath the surface of the earth), such as water in an aquifer.

**Q: Where is water stored in an aquifer?**

**A:** In the pores or void spaces within the material comprising the aquifer. In an aquifer comprised of sand or sandstone, water is contained within the tiny spaces between the grains of sand. In an aquifer comprised of fractured granite, the water is contained within the fractures.

**Q: What is a confined aquifer?**

**A:** As noted by the Executive Director in Response to Public Comment dated October 31, 2008 [Response No. 69, **Exhibit UEC-Holmes 12,** at p.46] and as further explained by Dr. Phillip C. Bennett, the term "confined aquifer" has different meanings. For example, in one use of the term, a confined aquifer is any aquifer that has a layer of material that has low impermeability both above it and below it. These layers of low permeability are called confining layer or aquitards, and they are often comprised of clay, shale or silt. Another meaning of the term "confined aquifer" is an aquifer that has an overlying confining layer and is saturated with water from bottom to top -- in other words, all of its pore space is filled with water. Using this meaning, a confined aquifer is contrasted to a water table aquifer. A water table aquifer contains within it the top of the water-saturated part of the subsurface, which is called the water table. In a water table aquifer, the pores overlaying the water table are filled with air. Regardless of the definition of confined aquifer that is employed, a single aquifer can be confined in some places and not in others. Each of the definitions of the term "confined aquifer" places differing emphases on the nature of the confinement.

**Q: Describe the differences between how surface water flows over the earth's surface and how groundwater flows through an aquifer.**

A: Surface water flow is readily demonstrated by a river. In a river channel, most of the flow has little contact with the bed or banks of the river. As a result, there is very little friction exerted on the flow of the water. Consequently, river flow is fast and typically creates complex boils and eddies. We describe such flow as turbulent. To travel through most aquifers, groundwater must move from one small pore to another within the permeable rock or other host material. Thus, unlike surface water flow, groundwater flow has a nearly infinite contact area with the solid particles comprising the aquifer. Groundwater flow is controlled by the friction that results from water particles moving across rough surfaces and through tiny channel ways between pores. The resulting flow is slow and is not turbulent. It is described as laminar. Darcy's Law, which is the fundamental equation used by hydrologists, is founded on the fact that groundwater movement is dominated by friction and is laminar.

**Q: How does the flow rate of surface water compare to the flow rate of groundwater?**

A: Turbulent flow in a river is typically measured in feet per *second*. Laminar flow in an aquifer is measured in feet per *year*.

**Q: Are there other major differences between how surface water flows over the earth's surface and how groundwater flows through an aquifer?**

A: Yes. While surface water always flows down-gradient (*i.e.*, from higher elevation to lower elevation), groundwater does not always do so. Rather, as further explained by Dr. Bennett in his testimony, groundwater flows from higher hyrdraulic head to lower hydraulic head.

**Q: Does the nature and composition of the materials in an aquifer affect how groundwater behaves within the aquifer?**

**A:** Yes. From a hydrological perspective, two important characteristics of material comprising an aquifer are its porosity and permeability. Porosity measures the volume of void space in a material as compared to its total volume, which determines how much water it can hold. The porosity of unconsolidated material is determined by the amount of space between the grains – in other words, how tightly the grains are packed together, which depends upon the shape, size and uniformity of the grains. (In poorly sorted sediments, finer grains tend to fill in the spaces between larger grains, resulting in lower porosity.) Permeability, on the other hand, measures the ability of a porous material to allow water to flow through it. Even highly porous materials can have low permeability if the pores are so small or poorly connected that water cannot move with ease from one pore to another. Thus, the permeability of a material depends not only on how porous it is, but also on the abundance and size of the *connections* between the pores. As Dr. Bennett explains in his testimony, the permeability of a material is one of the factors that determines hydraulic conductivity, which is the rate at which water can travel through a material.

**Q: How does permeability vary in aquifers comprised of unconsolidated materials?**

**A:** The permeability of unconsolidated materials in aquifers varies tremendously. For example, gravel is between ten to a thousand times more permeable than clean sand (depending upon whether the sand is fine or coarse) and 10,000 times more permeable than muddy sand.

Moreover, gravel is at least 100 million times more permeable than shale or clay.

**Q: What does the term "water quality" mean?**

A: Water quality is a statement about the potential uses of groundwater. Human consumption is just one potential use for water. In general, good water quality for purposes of human consumption means low total dissolved solids (TDS), low amounts of constituents that might pose a health risk (such as dissolved metals or nitrate), and low amounts of constituents that make water corrosive or unpalatable (such as H2S or iron). Dominant dissolved constituents in groundwater include sodium, calcium, bicarbonate, chloride, and sulfate.

**Q: What are the standards by which water quality is generally determined for purposes of human consumption?**

A: As Craig Holmes testified, water quality for purposes of human consumption is generally determined by reference to the primary and secondary drinking water regulations promulgated by the U.S. Environmental Protection Agency (EPA). As explained by Mr. Holmes, the primary drinking water regulations establish maximum contaminant levels ("MCLs") for contaminants that may pose a health risk to humans, while the secondary drinking water regulations establish MCLs for constituents that may negatively impact the odor or appearance of water.

**Q: Previously, I asked you about the rate of groundwater flow in an aquifer. You also testified that the levels of various constituents in groundwater determine its relative quality. When groundwater flows through an aquifer, do the constituents in it move at the same rate as the groundwater?**

A: Not necessarily. Various factors cause many dissolved constituents to move more slowly than the groundwater. For example, uranium and other trace metals in groundwater interact with clays and other solid materials in the aquifer matrix, which slows their migration. Flow dispersion through the heterogeneous aquifer matrix may also slow the migration rate of dissolved constituents -- in other words, because constituents are moving through a complex network of tiny channels between pores of various sizes, the pathway of a given constituent through the aquifer may be circuitous and meandering. Nevertheless, there are some constituents (such as chloride) that are able to flow at the same velocity as the groundwater because they are highly soluble and do not interact with other elements in the aquifer matrix. For this reason, chloride mapping is used to interpret natural groundwater flow patterns. Likewise, because in situ mining fluid may contain high levels of chloride, an increase in chloride levels in monitor wells is seen as an early indicator of a possible excursion.

## III.

## URANIUM: BASIC FACTS AND CONCEPTS

**Q: What is uranium?**

**A:** Uranium is the heaviest of the naturally-occurring elements on the periodic table. It has the chemical symbol U. In its pure metallic form, uranium is a silvery white metal that is nearly twice as dense as lead. Uranium is sensitive to a chemical reaction known as redox, and it naturally changes form as a result of that chemical reaction.

**Q: What is redox?**

**A:** Redox (which is shorthand for reduction-oxidation) is a chemical reaction in which the oxidation number (oxidation state) of an element's atoms is changed. It entails a chemical process that can go two ways: oxidation and reduction. Oxidation is an *increase* in the oxidation number of an atom, which generally occurs through the loss of electrons. Reduction is a *decrease* in the oxidation number of an atom, which generally occurs through the gaining of electrons. Substances that have the ability to oxidize other substances are known as oxidants.

Oxidants include oxygen, iron oxide, sulfates, and nitrates. Substances that have the ability to reduce other substances are known as reductants. Reductants include naturally-formed iron sulfide minerals, hydrogen sulfide, and hydrocarbon liquids and gases.

**Q: What does it mean to say that uranium is redox sensitive?**

**A:** It means that uranium readily participates in the reduction-oxidation chemical reactions.

**Q: How so?**

**A:** When in reduced form, uranium will readily react with oxidants and thereby become oxidized. When uranium is oxidized, it becomes readily soluble. Thus, barring other chemical reactions, it will move with groundwater. Conversely, when in oxidized form, uranium will readily react with reductants and thereby become reduced. When uranium is reduced, it precipitates – in other words, it drops out of solution and into mineralized form.

**Q: Where is uranium found?**

**A:** Trace amounts of uranium are naturally present in rocks, soil, and water almost everywhere on earth. The concentrations of uranium vary according to where it is found and what other substances are present. For example, granite contains uranium at a concentration of approximately four parts per million – in other words, 999,996 parts of other elements comprising the granite (such as silica) to every four parts of uranium.

**Q: What is uranium ore?**

**A:** Uranium ore is a mineral deposit containing concentrated amounts of uranium that is suitable for mining. To be suitable for mining, a deposit must contain uranium in sufficient richness and of sufficient quantity to be economically extractable for the nuclear fuel market. The economic value of a deposit depends on, among other things, richness (grade), total quantity, depth below the land surface, associated metals, geological setting, access to processing facilities, local infrastructure, and market prices. As Mr. Holmes explains in his testimony, in Texas, a deposit containing uranium at a concentration of 300 parts per million (0.03%) is generally economically recoverable.

**Q: Where is uranium ore found?**

**A:** While uranium is ubiquitous, uranium ore is not. It is found in just a limited number of places. Uranium ore is distributed worldwide, and only about twenty-one countries export uranium. In the uranium mining industry within the United States, the most significant uranium ore reserves are located in sandstone formations in the Wyoming basins, on the Colorado Plateau, and in the South Texas Uranium Province.

**Q: Is uranium naturally radioactive?**

**A:** Yes, uranium naturally emits radiation. However, the level of radiation emitted by natural uranium is very low.

**Q: Why and how does uranium emit radiation?**

**A:** Uranium occurs in nature as a mixture of different isotopes. An isotope is a variant on a basic element. Every atomic nucleus in almost all normal matter is made of both protons and neutrons. If an element forms atoms that have two or more different numbers of neutrons in the nucleus, it is said to have two (or more) isotopes. Many isotopes are stable, but in some isotopes, the imbalance between the number of protons and neutrons makes the nucleus of the isotope unstable. This instability in the configuration of the nucleus can naturally result in nuclear decay, which is the process in which an unstable nucleus spontaneously disintegrates and emits radiation. The product of nuclear decay is a "daughter" isotope that, in turn, may decay. Thus, as a radioactive chemical element decays, a chain of other chemical elements known as daughter products is formed. Each daughter product decays to another element, which in turn decays further until finally reaching an element that is stable.

**Q: What does the term "radioactive half-life" mean?**

A: Radioactive half-life means the amount of time it takes for half a sample of an isotope to decay radioactively. Some radioactive chemical elements decay very quickly (short half-life) and, therefore, emit high levels of radiation. Others decay very slowly (long half-life), and, therefore, emit low levels of radiation.

**Q: What is the half-life of uranium?**

A: It depends on the isotope. Natural uranium is comprised almost entirely of two isotopes -- uranium-238 and uranium-235, which have different levels of stability and thus different half-lives. Uranium-238 is by far the most abundant uranium isotope, comprising 99.28% of all natural uranium. It is also the most stable uranium isotope. In fact, it has a half-life of about 4.5 billion years, which is close to the age of the Earth. As a result, uranium-238 decays very slowly and thus emits a very low levels of radiation. Uranium-235, while less stable than uranium-238, still has a long half-life of about 700 million years. Moreover, it only comprises 0.71% of natural uranium. Thus, the overall radioactivity level of natural uranium is very low.

**Q: What are the daughter products of uranium?**

A: It varies depending on the isotope. The radioactive daughter products of uranium-238 include radium-226 and radon gas. The radioactive daughter products of uranium-235 include radium-223 and radon gas. In either case, the stable element that is formed at the end of the chain of decay is lead.

## IV.

## SOUTH TEXAS URANIUM PROVINCE:

## THE EXISTENCE AND DEVELOPMENT OF URANIUM ORE BODIES AND THEIR NATURAL EFFECT ON GROUNDWATER QUALITY

**Q: In Texas, where is uranium ore found?**

**A:** Uranium deposits have been found in various places across the Texas coastal plain, in the Pan Handle and High Plains, and in volcanic rocks of Trans-Pecos Texas. However, the only commercial uranium mining in Texas has occurred in the South Texas Uranium Province.

**Q: Can you identify the document attached as Exhibit UEC-Galloway 2 to this prefiled testimony?**

**A:** Yes, it is a map showing the location of the South Texas Uranium Province.

**Q: Within the South Texas Uranium Province, where is uranium ore found?**

**A:** Ore bodies have been found in a number of geological formations throughout the South Texas Uranium Province, including the Carrizo, Whitsett, Catahoula, Oakville, and Goliad formations. Together, these various host formations (which are roughly stacked one on top of another) encompass several thousand feet of sedimentary deposits, several major and minor aquifers, and more than 35 million years of geologic time.

**Q: Can you describe a typical ore-bearing formation in the South Texas Uranium Province?**

**A:** The ore-bearing formations in the South Texas Uranium Province are generally comprised of stacked layers of fine to course sand and/or sandstone separated from one another by layers of clay, shale, or silt.

**Q: How do the sand/sandstone layers differ from the clay/shale/silt layers?**

**A:** The sand/sandstone layers, which host the uranium deposits, are water-bearing and highly permeable. They often comprise all or a part of an aquifer. The clay/shale/silt layers, while also water-bearing, have low permeability. As a result, they serve as confining layers between the sands. Typically, the hydraulic conductivity of the sand or sandstone layers in the South Texas Uranium Province is 1,000 to 10,000 times that of the confining layers that separate them.

**Q: How were these formations formed?**

**A:** As I previously explained, sedimentary rocks, including sandstone, are formed from sediment that eroded from the earth's surface and was then transported by wind, water, or glaciers and deposited into a basin. The uranium-hosting formations in the South Texas Uranium Province were formed by large river systems. The sediment comprising these formations was transported by a large system of ancient, meandering and braided rivers that flowed across the northwest coastal plain to the Gulf of Mexico during the Eocene to Miocene ages, 6 to 55 million years ago. These rivers carried sediment, which they deposited onto the ancient coastline of what we now know as the Gulf of Mexico basin. As the sediment accumulated, it formed the various layers of intermixed sheet and tabular-shaped deposits that comprise these host formations.

**Q: What caused the layering that is present in these formations?**

**A:** When the rivers were running within their established channels, the sediment that they transported and deposited consisted of fine to coarse sand and pebbly sand with some lenses of gravel. These deposits are called channel fill deposits. Storms in the drainage basins caused the rivers to flood or crest their natural levees periodically. During these times, the sediment that they transported and deposited outside their channels consisted largely of clay and silt. These deposits are called flood basin, levee, and crevasse splay deposits. Through geologic time, river channels switched back and forth across the coastal plain. These cyclical changes in the flow of the rivers thus caused the layering of channel fill sand and flood plain clay/silt/shale that is present in these formations.

**Q: Can you identify the document attached as Exhibit UEC-Galloway 3 to this prefiled testimony?**

A: Yes, it is an illustration of a fluvial formation deposited by an ancient river. This is the type of formation that exists in the South Texas Uranium Province. The tabular sand units in these formations are often host units for uranium ore.

**Q: What is a fault?**

A: A fault is a fracture in a sedimentary rock layer that results from displacement. By displacement, I mean that the block of rock on one side of the fracture moves relative to the block of rock on the other side.

**Q: What are the Wilcox growth faults?**

A: The Wilcox growth faults originated in the Wilcox formation, which was deposited 50 to 60 million years ago when the edge of the early Gulf of Mexico continental shelf lay along what is now the inner coastal plain of Texas. At the time that the sedimentary layers comprising the Wilcox formation were being deposited, faults grew at a high rate. Ultimately, the faults resulted in displacements across individual fault planes of thousands of feet. Once formed and buried by thousands of feet of younger deposits, these faults remained zones of weakness. Later structural adjustments periodically reactivated these older faults. The faults then extended up into overlying, younger beds. In these younger units, the faults show modest displacement (or offset), usually measured in tens to a few hundred feet.

**Q: Can you identify the document attached as Exhibit UEC-Galloway 4 to this prefiled testimony?**

**A:** Yes, it is a photograph of an open pit uranium mine at Ray Point located in Live Oak County. It shows a shallow fault cutting through the ore-bearing sandstone of the Oakville formation, which I have included in my testimony for illustrative purposes.

**Q: Describe the history of uranium mining in the South Texas Uranium Province.**

**A:** Initial mining began in Texas in the 1960's and has continued until the present. Early mining was exclusively by open pit, with surface mills (located in Karnes County) processing ore trucked to the mill site. In situ mining emerged in the mid-1970's as an alternative technology that is well-suited for the South Texas Uranium Province. As noted by the Executive Director in Response to Public Comment dated October 31, 2008 [Response No. 38, **Exhibit UEC-Holmes 12,** at p.28], in situ mining has several advantages as compared to open pit mining, including less surface destruction, fewer tailings (that is, crushed rock left over after the uranium has been removed in a processing mill), and less overburden wastes (that is, overlying soil and rock removed to reach the uranium ore).

**Q: What is the original source of uranium in South Texas?**

**A:** The original source was volcanic ash that spread across North America from explosive volcanoes in northern Mexico, West Texas, Colorado, and Wyoming. The ash contained small amounts of uranium and other metals (parts per million). The ash washed down the ancient rivers and was deposited along the Gulf coastal plain. The uranium-bearing ash then became buried along with the other sedimentary deposits from the rivers.

**Q: What happened to the uranium as the ash became buried?**

**A:** As the ash was buried, it was readily dissolved. Through exposure to the atmosphere and the oxygen-bearing rainwater that percolated down through the ancient soils into the newly forming aquifers, the uranium in the ash was oxidized. Thus, as uranium was released from the ash into the oxidized rainwater and groundwater, it was highly soluble and moved with the water into the newly forming aquifers. This process became active as the aquifer formations began to be buried, perhaps a few million years after the host sandstone or other sediments were originally deposited along with the ancient coastline.

**Q: What happened to cause the soluble uranium to precipitate into ore?**

**A:** Eventually, the newly formed aquifers were buried deeper and deeper under newer sediment layers and formations. As the uranium-bearing groundwater moved deeper into the subsurface, it lost contact with the atmosphere and thus with the atmospheric oxygen. In addition, as the uranium-bearing groundwater moved deeper into the subsurface, it also encountered reductants. Such reductants include plant debris and other organic material buried with the host sediment, naturally-formed iron sulfide minerals, hydrogen sulfide, and hydrocarbon liquids and gases. Some reductants were deposited with the original sediment, while others migrated into or precipitated within the aquifer later in its history. These reductants reduced the dissolved uranium, which then precipitated into mineral form.

**Q: As uranium-bearing groundwater comes into contact with reductants in the subsurface, does all of the uranium precipitate into ore?**

**A:** No. As oxidizing waters intrude into a reduced area of a sandstone aquifer, an oxidation/reduction boundary is created. This boundary acts like a geochemical filter, causing uranium (and additional metals that have similar geochemical behavior, such as molybdenum and selenium) to precipitate (that is, to drop out of solution and into a mineralized form) on the down-flow side of the boundary. However, as uranium-bearing groundwater passes through an oxidation/reduction boundary, not all of the uranium precipitates into ore. Rather, a sinuous zone of mineralization of variable richness, width, and thickness forms along the oxidation/reduction boundary. While some of this sinuous margin may contain one or more uranium ore bodies, most of it will likely contain scattered mineralization or deposits that are not large enough, or do not have sufficiently rich concentrations of uranium, to constitute ore bodies. In other words, most commonly, uranium mineralization occurs in non-economic quantities.

**Q: In the South Texas Uranium Province, what were these reductants, and where did they come from?**

**A:** Throughout the South Texas Uranium Province, most of the subsurface environment is reducing. Most of the uranium-bearing sands in this region contain iron sulfide minerals (most commonly, the mineral pyrite, which is also known as fool's gold). Pyrite can form early from elements already in sediments, which is the process seen in most sandstone uranium deposits elsewhere in the world. Texas, however, is a bit different. The sulfur in the abundant pyrite found in South Texas uranium deposits came from rocks lying at the very foundation of the Gulf of Mexico basin, twenty thousand feet or more beneath the uranium-hosting aquifers. The sulfur entered these aquifers in the form of hydrogen sulfide in solution as large volumes of the deep water were introduced along Wilcox growth faults. This sulfur reacted with iron minerals that were already present in sediments comprising the aquifers to create the iron sulfide minerals, such as pyrite. This process reduced the parts of the aquifer into which the deep water was introduced.

**Q: Can you place a time frame on the significant events that resulted in the creation of these uranium-bearing formations in the South Texas Uranium Province?**

**A:** Uranium-rich ash from volcanic eruptions first arrived in abundance across what is now known as the South Texas Uranium Province about 35 million years ago, and it continued to arrive until as recently as 10 million years ago. Uranium mineralization began to form in the aquifers soon after the ash-rich sediment was deposited there and continued to form intermittently until after the youngest ash units arrived, which was as recently as ten million years ago.

**Q: Are the reductants that caused uranium deposits to form still present in the South Texas Uranium Province?**

**A:** Yes. In fact, as I mentioned previously, most of the subsurface environment is reducing.

**Q: How can a geologist tell the difference between oxidized and reduced portions of an aquifer?**

**A:** As I previously described, a geochemical boundary separates the part of an aquifer that is oxidized from the down-flow part that is reduced. These two geochemical zones are usually recognizable because of the color of the sediment or rock. The color variation is the result of the effect of redox on iron. Oxidized iron, which is reddish brown in color, adheres to sediment or rock. As a result, sediment or rock in oxidized areas are characterized by reds, browns, tans, and very light gray. Sediment or rock in reduced areas of an aquifer are characterized by grays and olive grays, which are the colors of finely dispersed iron sulfide minerals and iron-bearing clays.

**Q: Can you identify the document attached as Exhibit UEC-Galloway 5 to this prefiled testimony?**

**A:** Yes, these are photographs that I took of core samples from the South Texas Uranium Province showing typical color variations between oxidized and reduced rock.

**Q: Does the presence of uranium deposits affect groundwater quality in the South Texas Uranium Province?**

**A:** Yes. Groundwater in uranium-bearing aquifers in South Texas often contains elevated levels of uranium, its daughter products (particularly radium-226), or other metals that have similar geochemical behavior (such as molybdenum and selenium). Depending on local groundwater chemistry, uranium and associated metals in mineral deposits within aquifer sediments may show up in well water. This pattern is clearly shown by the fact that hundreds of water wells across the South Texas Uranium Province have elevated levels of uranium and associated metals.

**Q: Why is that?**

**A:** First of all, the fact that uranium ore bodies developed in South Texas tells us that we had an unusually rich, natural geologic source of uranium -- in this case, uranium-rich volcanic ash. Moreover, as described above, the presence of the ash combined with the geochemical and geological features of the aquifers in this area have resulted in the formation of uranium mineral deposits. Uranium deposits are present and widespread throughout the aquifers of the South Texas Uranium Province. The presence of these uranium deposits has a significant impact on water quality.

**Q: How does the presence of uranium deposits affect water quality?**

**A:** In several ways. First, it is well-established that water samples taken from wells drilled directly into uranium ore bodies commonly have high values of uranium. Moreover, even if a well is not drilled directly into a uranium ore body, it may still be drilled into a non-commercial uranium deposit or an area of scattered mineralization, which also results in elevated values of uranium. In addition, as uranium naturally decays, its daughter products (such as radium-226) are displaced from the ore bodies into nearby areas of the aquifer. Thus, as noted by the Executive Director in Response to Public Comment dated October 31, 2008 [Response Nos. 10 & 42, **Exhibit UEC-Holmes 12,** at pp.13, 30], wells that are located in or near uranium deposits, naturally have higher levels of uranium and uranium-related constituents, which may exceed the MCLs for those constituents.

**Q: Given that, what kind of groundwater quality would you expect to see in an area of an aquifer that contains significant amounts of uranium ore?**

**A:** I would expect the groundwater quality to be compromised. As the Executive Director in Response to Public Comment dated October 31, 2008 [Response No. 140, **Exhibit UEC-Holmes 12,** at p.83] explained: "Typically, premining groundwater quality of a production zone will have uranium and radium-226 levels that exceed [MCL]. There may also be uranium-indicator constituents, such as lead and arsenic, that exceed MCL." In fact, the natural presence of both uranium and its daughter products, including radium-226, in groundwater is used to explore for uranium deposits. The NURE (National Uranium Resource Evaluation) program of the 1970's undertook extensive groundwater sampling for just that purpose.

## V.

## REGIONAL GEOLOGICAL FRAMEWORK OF THE MINE PERMIT AREA

**Q: What is the regional geologic formation in which the Mine Permit Area is located?**

**A:** The Mine Permit Area is located within the Goliad Formation, which extends along the inner coastal plain from the Rio Grande River to near the Colorado River. The sand layers of the Goliad Formation comprise a part of the Evangeline aquifer. The portion of the Evangeline aquifer that is comprised of the Goliad Formation is known as the Goliad aquifer. The Evangeline aquifer also includes geologic units both above and below the Goliad Formation.

The Evangeline aquifer comprises a part of a larger aquifer system known as the Gulf Coast aquifer, which extends from Florida to Mexico.

**Q: What is the Goliad Formation comprised of?**

**A:** The Goliad Formation consists of fluvial deposits from the family of ancient rivers described above. It consists of stacked layers of channel fill deposits comprised of permeable sand or sandstone which are separated from one another by flood basin and related deposits comprised of silt, clay, or shale. These silt/clay/shale deposits are the confining units between the sands of the Goliad Formation.

**Q: How was the Goliad Formation in Goliad County deposited?**

**A:** The portion of the Goliad Formation located in Goliad County was deposited by a large, ancient river known as the Cuero River. The Cuero River was a part of a family of rivers described above that flowed across the northwest Gulf coastal plain six to fifteen million years ago during the Miocene age. Deposits of this ancient river extend about three thousand square miles beneath Goliad and adjacent counties. Because the Cuero River was meandering, it formed broad, tabular deposits that are typically thirty to sixty feet thick, thousands of feet to tens of thousands of feet wide and tens of miles long.

**Q: How thick is the Goliad Formation?**

**A:** The Goliad Formation thins from about 1000 feet in thickness in far South Texas to about 600-700 feet in the middle Texas coastal plain.

**Q: I'm going to ask you some questions specifically about the Goliad Formation in the Mine Permit Area. First, can you describe the layers that comprise the Goliad Formation in the Mine Permit Area?**

**A:** Yes. The Goliad Formation in the Mine Permit Area consists of four distinct channel fill sands, which are labeled Sands A—D in the Mine Application. Each of the sands is separated from one another by confining layers consisting of flood basin and related deposits comprised largely of clay. These confining layers are continuous throughout the Mine Permit Area. Thus, as illustrated by the visualizations that are attached to the testimony of Craig Holmes as **Exhibit UEC-Holmes 6** and **Exhibit UEC-Holmes 7**, each of the sands is completely separated from the sand above and below by a confining layer of clay.

**Q: Are the sands in the Mine Permit Area homogeneous or heterogeneous?**

**A:** A significant amount of heterogeneity is present within each of the sands. Within each sand, there is a fairly wide variety of grain size.

**Q: What is the direction of the groundwater flow in and around the Mine Permit Area?**

**A:** Regional groundwater flow is typical of coastal plain aquifers, that is, coastward. Thus, groundwater flow in the Mine Permit Area is generally to the southeast. Like other aquifers, however, flow is locally modified by surface topography, structures such as faults, and local aquifer sand body geometry. For the most part, the hydraulic gradient within the Mine Permit Area is relatively flat, resulting in a slow rate of groundwater flow.

**Q: Does the Mine Permit Area contain any faults?**

**A:** Yes. The Goliad Formation intersects the zone of Wilcox growth faults. Two extensions of Wilcox growth faults are present in the Mine Permit Area: 1) a relatively large, down-to-the-coast fault, which I will refer to as the Northwest Fault; and 2) a smaller, up-to-the-coast fault, which I will refer to as the Southeast Fault. The age of the faulting is younger than the Goliad Formation, probably dating as young as the Pliocene age, two to five million years ago. These faults are similar to the fault uncovered at the Ray Point mine and shown in **Exhibit UEC-Galloway 4**. The displacement of the sands across the Northwest Fault creates an effective barrier to the lateral flow of groundwater within the sands.

**Q: Can you describe the area between these two faults?**

**A:** The Northwest Fault and the Southeast Fault are about 4,500 feet apart. Between these faults is a typical structure called a graben – a block of land that is displaced downward between two converging faults, thus forming a kind of valley between them. (The valley is a subsurface structure. It is not a visible feature at the surface.)

**Q: How thick is the Goliad Formation in the Mine Permit Area?**

**A:** In much of Goliad County, the Goliad Formation is 600-700 feet thick. In the Mine Permit Area, however, the Goliad Formation is only about 400—500 feet thick; this is a truncated thickness because the Goliad Formation outcrops in the Mine Permit Area.

**Q: What does the term "outcrop" mean?**

**A:** An outcrop is an exposure of a sedimentary deposit or rock layer at the surface of the Earth. In most places in the Texas coastal plain, a layer of soil and vegetation (which is called the weathered zone) covers the underlying unweathered sedimentary deposits or rock layers, such that they are not directly visible at the surface.

**Q: Describe the outcrop in the Mine Permit Area.**

**A:** The top of Sand A, which is the shallowest of the sands in the Mine Permit Area, merges into the weathered zone and then crops out along the northwest margin of the Mine Permit Area, as illustrated by the visualization that is attached to the testimony of Craig Holmes as **Exhibit UEC-Holmes 7**. The outcrop area is on the up-thrown side of the Northwest Fault – in other words, outside of the graben. In the graben between the faults, a layer of clay overlies Sand A.

**Q: Can you describe the shape and approximate lateral extent of the sand layers comprising the Goliad Formation in Mine Permit Area?**

**A:** These sands are tabular-shaped deposits. As the Executive Director in Response to Public Comment dated October 31, 2008 [Response No. 115, **Exhibit UEC-Holmes 12,** at p.70] explained: "With the exception of Sand C, which thins out in the central part of the graben, sands of the Goliad Formation at this site occur as continuous sheets, not in discrete channels...." **Exhibit UEC-Galloway 3** provides a good illustration of how these tabular-shaped sands were formed. Only one of the sands shows lateral pinch-out (that is, termination) within the Mine Permit Area. This fact indicates that the sand bodies are broader than the dimensions of the Mine Permit Area, which is about one mile by two miles. Thus, the sands must be much more than five to ten thousand feet wide.

**Q: Approximately how thick are the sand layers comprising the Goliad Formation in the Mine Permit Area?**

**A:** Typically, these channel fill sands are each approximately thirty to fifty feet thick. In parts of the Mine Permit Area, sand body thicknesses approach one hundred feet. Here, two or more channel fill sands, each on the order of thirty to fifty feet thick, are superimposed to form a single sand body. Such superimposed channel fill deposits are common.

**Q: Can you describe the shape and approximate lateral extent of the clay layers in Mine Permit Area?**

**A:** The clay layers are widespread sheets that extend across and beyond the Mine Permit Area. This would be expected in fluvial deposits where flood plains cover much larger areas than do channel fills.

**Q: Approximately how thick are the clay layers in the Mine Permit Area?**

A: The confining layers of clay in the Mine Permit Area are between thirty and forty-five feet in thickness.

**Q: What do the materials you have reviewed suggest occurred in and around the Mine Permit Area with respect to the formation of uranium ore bodies?**

A: In my opinion, the process of uranium ore body formation that I described above occurred at the Mine Permit Area. The uranium ore bodies in the Mine Permit Area are directly analogous to the well-studied deposits found in the Catahoula and Oakville formations. The geologic setting of the Mine Permit Area tells the history of this portion of the Evangeline aquifer and the formation of the uranium ore found there. First, Sands A—D were deposited during the Miocene age by the Cuero River, a coarse, sandy, meandering river. During the Miocene age, the climate of South Texas was even drier than today. Consequently, the water table was deep and the river sediments were thoroughly leached and oxidized before being buried in the subsurface. Thus, the volcanic ash was leached of its uranium, and the soluble uranium then moved into the water-bearing sands. Later, deep, sulfide-rich water containing reductants in the form of hydrogen sulfide was introduced into these sands. This water most likely arrived during adjustments of the Wilcox growth faults that now cut through the Mine Permit Area. As groundwater containing the soluble uranium encountered reductants in the subsurface, the uranium precipitated as minerals.

**Q: Are reductants still present in the sands within the Mine Permit Area?**

A: Yes. Significant amounts of pyrite continue to be present in this area.

**Q: Can you identify the document attached as Exhibit UEC-Galloway 6 to this prefiled testimony?**

**A:** Yes, this is a photograph of a piece of pyrite recovered from the Mine Permit Area.

**Q: What effect does the presence of pyrite have on the sands within the Mine Permit Area?**

**A:** Because pyrite continues to be present in this area, significant portions of the sands are reducing. Even a very small amount of pyrite (*i.e.*, a fraction of one percent) can serve as an adequate reductant. The areas of the Mine Permit Area that are reducing can be readily identified by the color of the core samples taken by UEC in the process of drilling boreholes and wells in the area.

**Q: Can you identify the document attached as Exhibit UEC-Galloway 7 to this prefiled testimony?**

**A:** Yes, these are photographs of core samples from the Mine Permit Area showing the color variation between the oxidized and reduced portions of the sands. The gray colored rock and sediment are reducing. The tan colored rock and sediment are oxidized.

## VI.

## ISSUES REFERRED BY THE COMMISSION

### A.

### ISSUE G:

### DOES THE APPLICATION ADEQUATELY CHARACTERIZE AND DESCRIBE THE GEOLOGY AND HYDROGEOLOGY IN THE PROPOSED PERMIT AREA, INCLUDING FAULT LINES, UNDER THE APPLICABLE RULES?

## ISSUE Q:

## WHETHER THE GULF COAST AQUIFER IS A CONFINED AQUIFER IN THE AREAS OF GOLIAD COUNTY WHERE UEC WILL CONDUCT UIC ACTIVITIES

**Q: I'd like to ask you some questions that bear on the issue of whether or not the sands where UEC plans to mine constitute confined aquifers. First, is each of the sands, in the areas where UEC plans to mine, surrounded by confining layers both above and below the sand?**

**A:** Yes. Throughout the Mine Permit Area, each of the sands is separated from one another by thick, continuous layers of clay, which have low permeability. These confining layers average between 30 and 45 feet in thickness. In addition, there is a substantial layer of clay and caliche that overlies Sand A throughout the graben, which is the only area in which UEC plans to mine in Sand A. This overlying layer of clay and caliche is one hundred feet thick in places and has low permeability. As a result, the Executive Director in Response to Public Comment dated October 31, 2008 [Response No. 75, **Exhibit UEC-Holmes 12**, at p. 53] concluded that while recharge of Sand A does occur in the outcrop area on the up-thrown side of the Northwest Fault, it does not occur within the graben.

**Q: Have you formed an opinion regarding whether or not each of the sands are vertically confined from one another?**

**A:** Yes, in my opinion, each of the sands are vertically confined from one another.

**Q: What are the bases for that opinion?**

**A:** Each of the sands have different hydraulic heads and water chemistries. These facts support the interpretation of vertical confinement between the sands.

**Q: Does that vertical confinement extend to Sand A, such that Sand A is vertically confined from Sand B?**

A: Yes. In fact, the greatest difference in TDS values in water chemistry analyses and map patterns is between Sand A and Sand B. This fact supports the interpretation of vertical confinement between these two sands.

**Q: Can you identify the document attached as Exhibit UEC-Galloway 8 to this prefiled testimony?**

A: Yes, it is Table 5.5 of the Mine Application, which shows the various heads and water chemistries of the different sands.

**Q: Can you identify the documents attached as Exhibit UEC-Galloway 9 to this prefiled testimony?**

A: Yes, they are Tables 5.1 and 5.2 to the PAA-1 Application, which show the differing TDS values between Sand A and Sand B.

**Q: Can you identify the documents attached as Exhibit UEC-Galloway 10 to this prefiled testimony?**

A: Yes, they are Figures 5-1 and 5-2 to the PAA-1 Application, which show the differing map patterns of TDS values between Sand A and Sand B.

**Q: Earlier you discussed the role of the faults in the formation of the uranium ore bodies in the Mine Permit Area – specifically, as a conduit for the introduction of deep, reducing water from the Gulf Coast basin into the sands many millions of years ago. Do the two mapped faults in the Mine Permit Area currently serve as a hydraulic connection between the sands?**

A: No, the role of faults in the formation of uranium ore many millions of years ago does not mean that the faults are transmissive today. Rather, the transmission of deep waters along the faults was a geologically historical event of a limited duration. As further explained by Dr. Bennett in his testimony], there is no evidence suggesting that the faults currently serve as a hydraulic connection between the sands, and there is substantial data refuting that possibility.

**B.**

**ISSUE R:**

**WHETHER MINING FLUIDS WILL MIGRATE VERTICALLY OR HORIZONTALLY AND CONTAMINATE AN USDW (UNDERGROUND SOURCE OF DRINKING WATER)**

**ISSUE T:**

**WHETHER ANY USDWS WITHIN GOLIAD COUNTY WILL BE ADVERSELY IMPACTED BY UEC'S PROPOSED IN SITU URANIUM OPERATIONS**

**Q: Does your testimony have any bearing on the issue of whether or not mining fluids will migrate vertically or horizontally and contaminate an USDW (underground source of drinking water)?**

A: Dr. Phillip Bennett, a hydrogeologist, and Van Kelley, P.G., a hydrogeologist/modeler, will both be addressing the issues related to the flow and migration of fluids. However, the above opinions related to the structure and confined nature of the sands in the Mine Permit Area certainly bear on this issue.

**Q: Does this conclude your prefiled testimony in this docket?**

A: Yes.